STUDY THE STRUCTURAL AND ELECTRICAL PROPERTIES OF CdTe:Ag THIN FILMS

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Abstract

The influence of silver doped n-type polycrystalline CdTe film with thickness of 200 nm and rate deposition of 0.3 $nm.s^{-1}$ prepared under high vacuum using thermal co-evaporation technique on its some structural and electrical properties was reported. The X- ray analysis showed that all samples are polycrystalline and have the cubic zinc blend structure with preferential orientation in the [111] direction. Films doping with impurity percentages (2, 3, and 4) %Ag lead to a significant increase in the carrier concentration, so it is found to change from 23.493×10^{8} cm^{-3} to 59.297×10^{8} cm^{-3} for pure and doped CdTe thin films with 4%Ag respectively. But films doping with impurity percentages above lead to a significant decrease in the electrical conductivity and Hall mobility, so they are found to change from $6.3\times10^{-7}(\Omega.cm)^{-1}$ to $1.59\times10^{-7}(\Omega.cm)^{-1}$, and from 16.759×10^{2} $cm^{2}.(V.sec)^{-1}$ to 1.675×10^{2} $cm^{2}.(V.sec)^{-1}$ respectively, for pure and doped CdTe thin films with 4%Ag. And also the doping lead to change the kind of conductivity for thin films obtain, so we found that pure CdTe thin film is n-type and then convert to p-type when thin film doped with (2, 3, and4) %Ag.

Introduction

Thin films of II-IV semiconductors are currently used in many semiconductors devices such as photo-electrochemical cells, field effect transistors, detectors, photodiodes and photovoltaic solar cells [1]. CdTe with a direct band gap of 1.5 eV and high absorption coefficient (> 10^{4} cm^{-1}) is one of most promising semiconductor material for producing photovoltaic solar cells [2]. Also, doping CdTe thin films with different metal atoms produced considerable change in the optical, and electrical of the thin films properties[3], that make it useful in the technology of thin film devices[4] . As potential acceptors, the group Ib elements Cu, Ag, and Au are important impurities in II-VI compound semiconductors. Besides the acceptor like incorporation on substitution lattice sites, in addition, they are reported to occupy interstitial lattice sites[5], this fact was also emphasis by Chamonal et al.[6] , and Monemar et al.[7] . For fabrication of the CdTe films a variety of preparation techniques have been employed such as vacuum deposition [8], sputtering [9], electro deposition [10], metal-organic chemical vapor deposition [11], and close-space sublimation [2]. The vacuum evaporation method has some advantages such as: the amount of impurities included in the growing layer will be minimized, the tendency to form oxides will be considerably reduced and finally straight line propagation will occur from the source to substrate. This method has been employed for preparation of the CdTe, and CdTe:Ag thin films, but Wolf et el.[5], and Hamann et al.[12] have been employed the radiotracer Ag, and implanting radioactive method respectively for prepared CdTe:Ag thin films.

This paper analysis the effect of Ag doping on the structural and electrical properties of thermally evaporated CdTe thin films on glass substrate.

Experimental

Un-doped and Ag-doped CdTe thin films were grown by thermal co-evaporation onto corning glass substrates kept at temperature (473K) under vacuum($\sim2\times10^{-5}$Torr) of the CdTe powder (purity 99.999% obtained from Blazers, Switzerland) using Edward coating unit model 306A. The source -substrate distance was about 15 cm. A thermocouple placed in contact with substrate in order to remain the substrate temperature practically constant during the deposition. The film structures were investigated by using Cu-K_{α}

radiation (λ=1.54Å) in the 2Θ range (20°-60°). For electrical measurements, samples with planar geometry have been prepared using deposited aluminum thin film as contact electrodes were deposited in vacuum onto the substrate before film deposition by using suitable masks. Keithley (616) electrometer was used for resistance measurement in the temperature rang of (291-495) K.Hall effect was carried out by using D.C. power supply (0-40) Volt, and two keithey to measure the passing current (I), and Hall voltage (V_H) that emerge after applied constant transverse magnetic field (B=0.257Tasla). The measurements of X-ray diffraction and D.C. conductivity were made in the geology scanning office, and thin film laboratory, college of science, university of Baghdad respectively.

Result and Discussion

These results include X-ray diffraction examination of CdTe powder, pure CdTe films, and films doped with (2, 3, and 4) % silver, also the result of electrical measurements (D.C.conductivity, and Hall effect) of films by using aluminum electrodes have been analyzed.

1. Structural properties :

XRD pattern of the CdTe powder and CdTe films [pure, and doped with (2, 3, and 4) % Ag] are shown in Fig. (1). The spectrum of CdTe powder is seen to exhibit four sharp peaks corresponding to the cubic phase of CdTe as compared with the standard values in ASTM cards. But the spectrum of CdTe films is seen to exhibit three sharp peaks and all films deposited show the highest peak near 2Θ equal to 24^o, suggesting that the crystal structure of the CdTe films is zinc blende with a preferential orientation of the (111) plan. No diffraction peak corresponding to metallic Cd, Te,or other compound was observed. This result agreement with Sanyal at el.[13] for pure CdTe films. So the experimental results show that the above impurity percentages don't make any clear change at the main features of diffraction pattern of CdTe films.

Table (1) summaries the values of Miller indices (hkl), 2 theta (2Θ), and the interplaner distance (d) for powder and prepared CdTe samples.

2. Electrical properties:

Fig. (2.a, b, c, and d) show the variation logarithm of the conductivity (lnσ) with1000\T for pure, and dopant CdTe thin films with (2, 3, and 4) % Ag. These figures show that there is dependence of conductivity on temperature and there are two transport mechanisms giving rise to two activation energies (E_{a1}, E_{a2}) throughout the temperature range (291-434)K, the first activation energy (E_{a1}) occurs at higher temperature, within rang (384-434)K, and this is due to conduction of the carrier excited into the extended states beyond the mobility edge, while the second activation energy (E_{a2}) occurs at lower temperature, within rang (291-380)K, and the conduction mechanism of this stage is due to carrier transport to the localized states near the valence and conduction band.

The D.C. conductivity was determined according to the relation ($\sigma_{d.c}$=L\R.W.t_h) where L is the distance between the electrodes, R is the measured electrical resistance of the film, W is the width of the electrodes, and t_h is the thickness of the film, and also the activation energy (E_{a1}, E_{a2}) were determined according to the relation $\sigma_{d.c}=\sigma_0 exp(-E_a\backslash k_B T)$, where σ_0 is the minimum electrical conductivity, T is the absolute temperature, and k_B is the Boltzmanś constant. From Table (2), the electrical conductivity is found to decrease from 6.3×10^{-7} $(\Omega.cm)^{-1}$ to $1.59\times10^{-7}(\Omega.cm)^{-1}$, while the activation energy (E_{a1}) is found to increase from 0.774 eV to 1.063 eV for pure and doped CdTe thin film with 4%Ag respectively. This behavior of $\sigma_{d.c}$ and E_{a1} with doping percentages might be due to creating an acceptor levels near valence band.

Hall effect measurement give information about the electrical properties such as type of charge carriers of the semiconductors material, Hall coefficient [R_H= (V_H/I) × (t_h/B)], concentrations of charge carriers (n_H=1/R_H.e), where e is the electron charge, and Hall mobility ($\mu_H=\sigma|R_H|).R_H$ for pure CdTe thin films is negative since Hall voltage decrease with the increase current as shown in Fig. (3.a), this means that they are of n-type, i.e. conduction is dominated by electron. This indicate to the cadmium interstitial density is much higher than the tellurium vacancy density [14], but R_H for CdTe thin films doping

with (2,3,4)%Ag is positive since Hall voltage increase with increasing current as shown in Fig. (3.b, c, and d), this means they are of p-type, i.e. conduction is dominated by holes, it is attributed to the acceptor impurity (Ag).

Table (2) summaries the values of R_H, n, and μ_H. It can be noticed that the value of n increase from $23.493\times10^{8}cm^{-1}$ for pure CdTe thin films to $59.297\times10^{8}cm^{-1}$ when films doped with 4%Ag. This can be explained by the fact that the impurity (Ag) incorporation on substitution lattice site. And the value of μ_H decrease from $16.759\times10^{2}(cm^{2}\backslash V.sec)$ to $1.675\times10^{2}(cm^{2}\backslash V.sec)$ for pure and doped CdTe thin films with 4%Ag. The decreasing in mobility is due to various scattering mechanism which occur by the grain boundaries, lattice atom vibration impurities, and defects, for all these reasons the mobility should decrease with increasing impurity percentage so the electrical conductivity decrease.

Conclusion

The influence of impurity percentages (2, 3, and 4) %Ag was investigated on the structural and electrical properties for CdTe films evaporated onto well cleaned glass substrates at temperature equal to 473K by thermal evaporation under a pressure of~10^{-5} Torr. By analysis of X- ray diffraction it is found that all CdTe films exhibit a polycrystalline structure. The predominant peak near 2Θ equal to 24° indicates that the CdTe films are of zinc- blend structure with a preferential orientation along the (111) plane.

The carrier concentration (n) of dopant films is higher than those of un-doped films and it is increase with increasing impurity percentages, but the electrical conductivity (σ) of do pant films is lower than those of undopant films and it is decrease with increasing impurity percentages.

It can be concluded that doping CdTe thin film with Ag percentages above is necessary to produce films with given properties for a specific application.

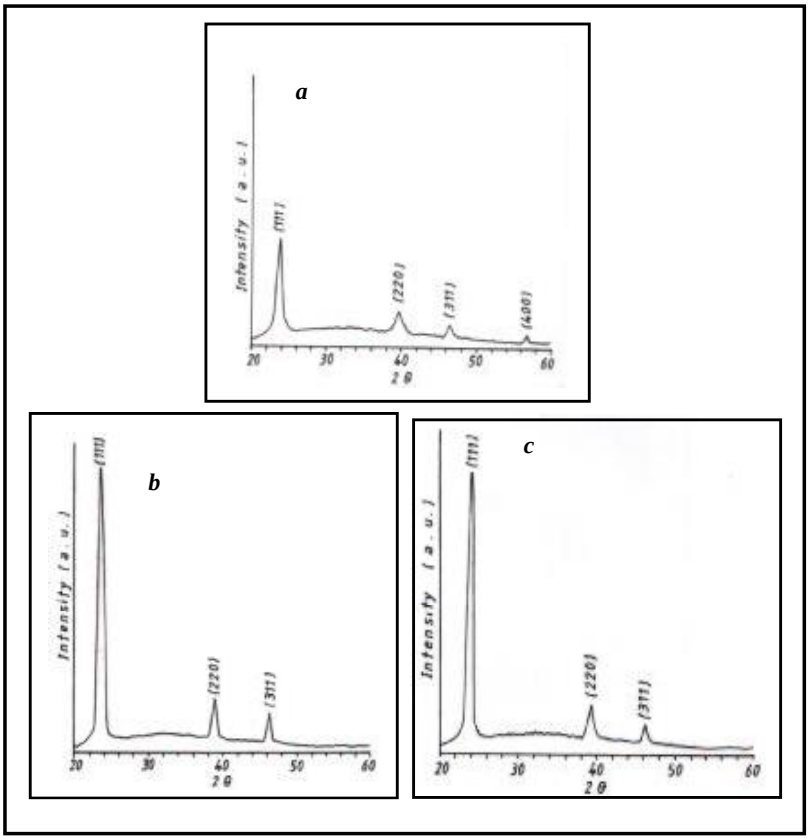

Fig. (1): The X-ray diffraction spectra of: a- CdTe powder. b- pure CdTe thin films. c- CdTe thin film + (2, 3, 4) %Ag.

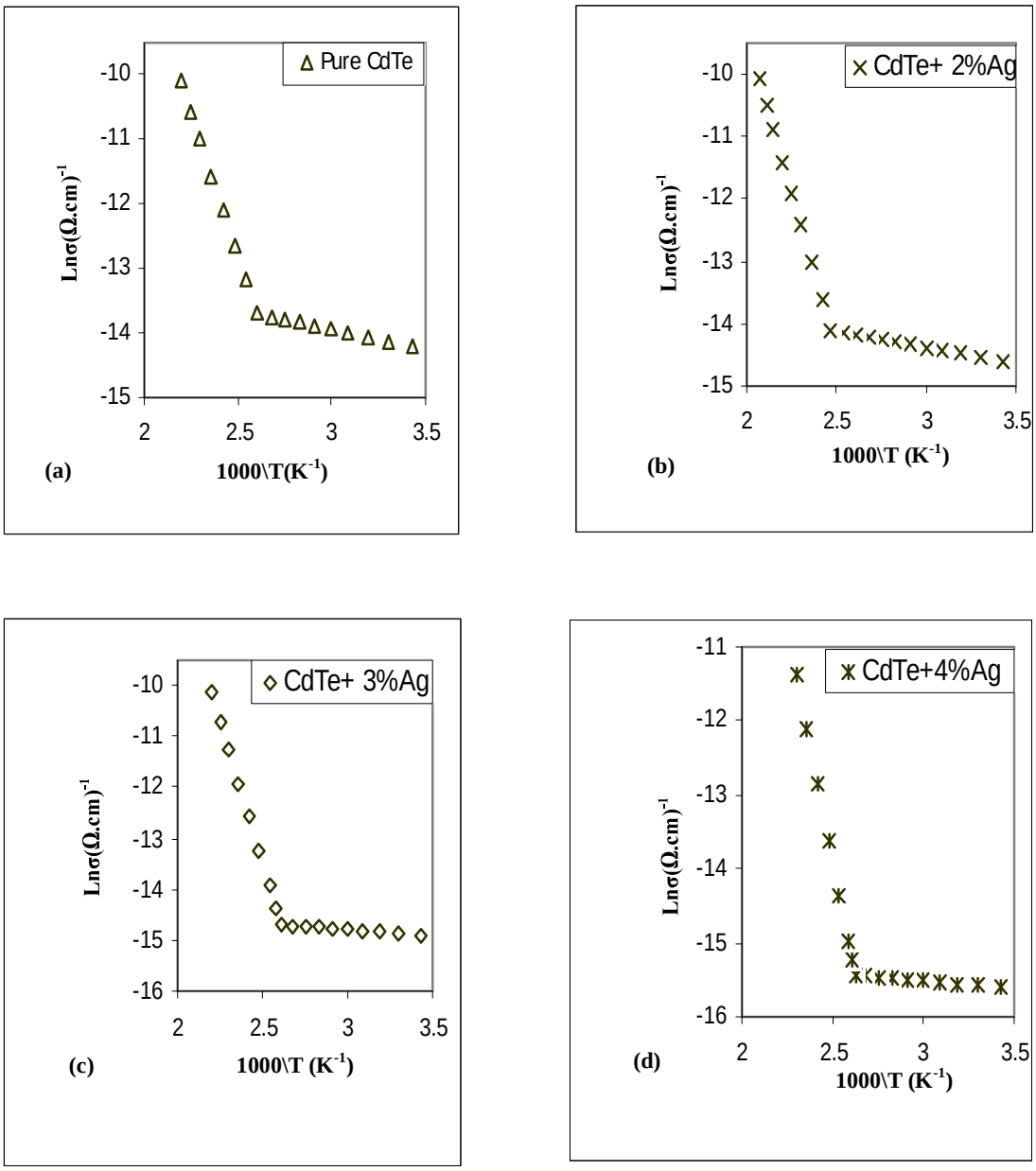

Fig. (2): The plots of Lnσ vs. 1000\T for:
a- Pure CdTe thin film. b- CdTe thin film+2%Ag.
c- CdTe thin film+3%Ag. d- CdTe thin film+4%Ag.

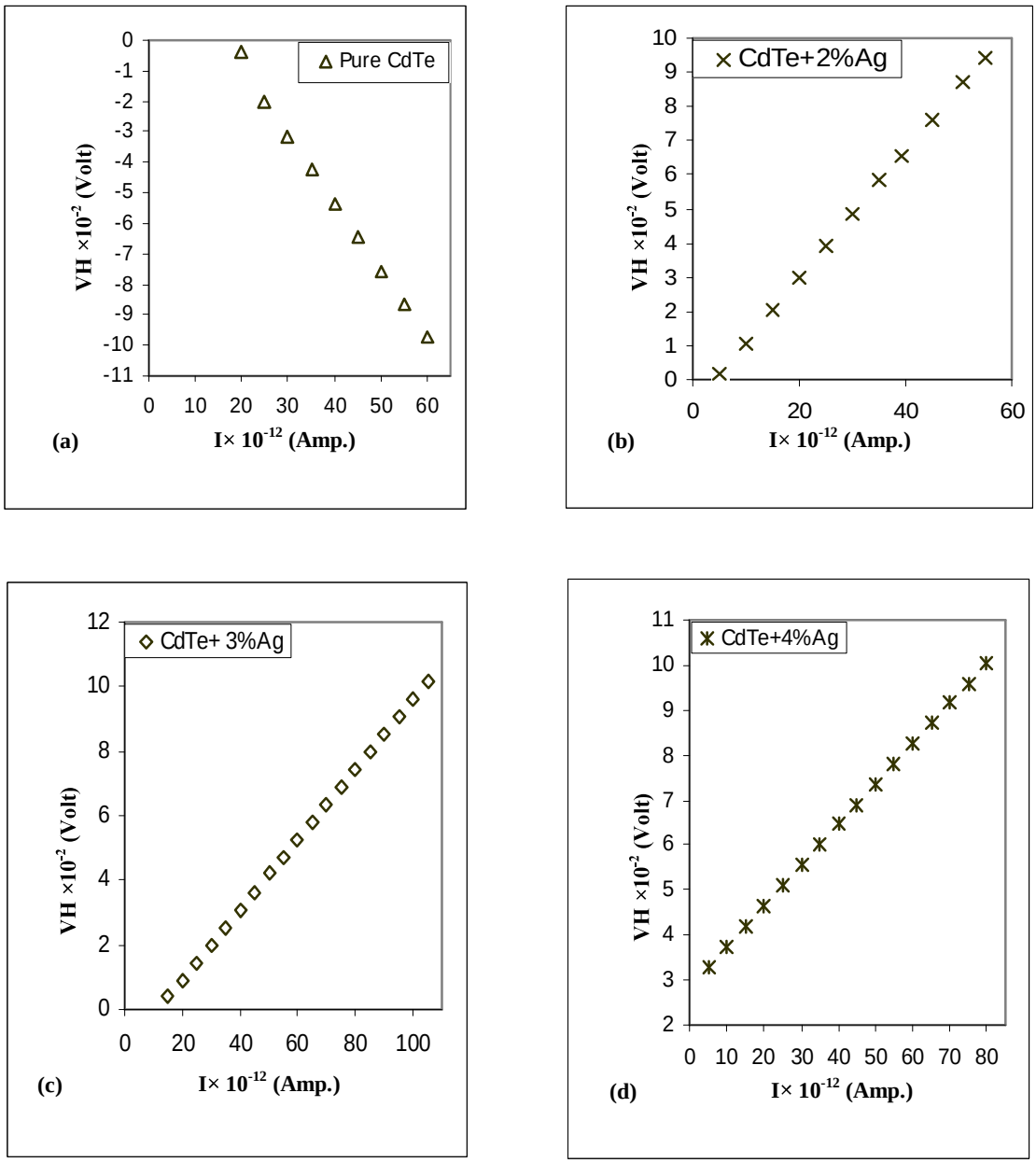

Fig. (3): The relationship between Hall voltage and Passing current for:
a- Pure CdTe thin film. b- CdTe thin film+2%Ag.
c- CdTe thin film+3%Ag. d- CdTe thin film+4%Ag.

Table (1)
The structural parameters of CdTe powder and prepared CdTe samples obtain from XRD diffraction.

Sample	hkl	2Θ(deg)	d(Å)
CdTe Powder	111	23.9	3.719
	220	39.5	2.281
	311	46.6	1.946
	400	56.8	1.619
CdTe Thin Films	111	23.7	3.756
	220	39.1	2.301
	311	46.4	1.956
CdTe Thin Films+ (2,3, and 4)%Ag	111	23.8	3.737
	220	39.3	2.291
	311	46.2	1.964

Table (2)
The electrical parameters of CdTe and CdTe:Ag films obtain from D.C. and Hall effect measurement.

Sample	$(\sigma_{d.c})\times10^{-7}$ $(\Omega.cm)^{-1}$	E_{a1} (eV)	E_{a2} (eV)	$R_H\times10^{9}$ $(cm^{-3}.C^{-1})$	$n_H\times10^{8}$ (cm^{-3})	$\mu_H\times10^{2}$ $cm^2.(V.sec)^{-1}$
Pure CdTe	6.3	0.774	0.052	-2.66	23.493	16.759
CdTe+2%Ag	4.45	0.868	0.042	2.178	28.693	9.692
CdTe+3%Ag	3.28	0.953	0.02	1.268	49.259	4.161
CdTe+4%Ag	1.59	1.063	0.017	1.054	59.297	1.675

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الخلاصة

تمت دراسة تأثير التطعيم بالفضة على بعض الخواص التركيبية والكهربائية لاغشية تيليرايد الكادميوم المتعددة البلورات ومن النوع السالب المحضرة بسمك200 nm وبمعدل ترسيب $0.3\ nm.\ s^{-1}$ باستعمال تقنية التبخير الحراري المزدوج في الفراغ . تحليل الاشعة السينية اوضح بان جميع النماذج المحضرة هي متعددة البلورات وتمتلك التركيب المكعبي مع التوجية المفضل[111] . أدى تطعيم أغشية تيليرايد الكادميوم بالفضة وبالنسب %(2,3,4) الى حصول زيادة هامة في تركيز حاملات الشحنة،حيث وجد بأن تركيز حاملات الشحنة يتغير من $23.493\times10^{8}cm^{-3}$ الى $59.297\times10^{8}cm^{-3}$ بالنسبة لاغشية تيليرايد الكادميوم النقية والمطعمة بالفضة بنسبة 4%. بينما ادى تطعيم الاغشية بالفضة وبالنسب اعلاة الى حصول تقصان هام في التوصيلية الكهربائية وتحركية هول، حيث وجد بأن التوصيلية الكهربائية وتحركية هول تتغير من $6.3\times10^{-7}(\Omega.cm)^{-1}$ الى $1.59\times10^{-7}(\Omega.cm)^{-1}$, ومن $16.759\times10^{2}cm^{2}.(V.sec)^{-1}$ الى $1.675\times10^{2}cm^{2}.(V.sec)^{-1}$ على التوالي بالنسبة لاغشية تيليرايد الكادميوم النقية والمطعمة بالفضة بنسبة4%. كما أدى التطعيم الى تغير نوع التوصيلية للاغشية المحضرة، حيث وجدنا ان نوع حاملات الشحنة لغشاء تيليرايدالكادميوم النقي هوn-type ويتحولp-type عندما يطعم الغشاء بالفضة وبالنسب %(2,3,and 4).